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INTERNAL COMBUSTION ENGINE INSTALLATION WITH A DIRECTLY INJECTED GASOLINE ENGINE AND A CATALYST SYSTEM

The invention relates to an internal combustion engine installation with the distinguishing features named in the introductory portion of claim 1.

For the aftertreatment of exhaust gases of internal combustion engines, it is generally customary to purify the exhaust gases catalytically. For this purpose, the exhaust gas is passed over at least one catalyst, which converts one or more pollutant components of the exhaust gas. Different types of catalysts are known. Oxidizing catalysts promote the oxidation of unburned hydrocarbons (HC) and carbon monoxide (CO), while reducing catalysts support the reduction of nitrogen oxides (NO_x) of the exhaust gas. Furthermore, 3-way catalysts are used, in order to catalyze the conversion of the three aforementioned components (HC, CO, NO_x) simultaneously. However, a 3-way catalysts can be used only if the ratio of air to fuel is strictly stoichiometrical at $\lambda = 1$.

For vehicles with a directly injected gasoline engine, which can also be operated in a stratified manner, catalyst systems of a comparatively large volume KV > 0.9 x the engine displacement VH are used. This is the case particularly for vehicles, which attain an HC emission of less than 0.07 g/km and an NO_x emission of less than 0.05 g/km with catalysts, which are not damaged by heat in the Neuen Europäischen Fahrzyzklus (New European Driving Cycle, NEFZ).

Aside from these directly injected gasoline engines, which can be operated up to an effective average pressure of about 3 bar as well as an rpm of about 3000 in the stratified charge mode, directly injected gasoline engines are known,

which can be operated in the stratified mode only to a very limited extent, if at all, in a very limited idling range (Alfa 2.0 JTS, The new Alfa Romeo 2 L JTS engine with Direct Gasoline Injection, 10, Aachener Fahrzeug- und Motorenkolloquium 2001). Analogously to the directly injected gasoline engines, which can be operated in the stratified mode, these vehicles and engines also have catalyst systems of a relatively large volume.

Admittedly, catalyst systems of large volume reliably produce low emissions. However, as is well known, noble metals are used to produce the catalysts, so that high costs are disadvantageously associated with catalyst systems of large volume.

The invention is therefore based on the objective of providing internal combustion engine installations with a directly injected gasoline engine and a catalyst system, which, while maintaining the emissions comparably low, can be produced at a lower cost with respect to the catalyst system than can internal combustion engine installations of the state-of-the-art.

This objective is accomplished by an internal combustion engine installation with the distinguishing features named in claim 1.

Pursuant to the invention, an internal combustion engine installation is provided, which has a directly injected gasoline engine, which can be operated in a stratified manner to only a slight extent, if at all, and a catalyst system, which is disposed downstream from the gasoline engine and has at least one catalyst, the catalyst system having a total volume (KV) of 0.8 to 0.5 x the engine displacement (VH) or of 1.3 to 0.7 L per 100 kW of engine power (PNENN) and for which the average specific noble metal loading of the catalyst or catalysts of the catalyst system is less than 3.59 g/dm^3 (100 g/ft^3) preferably less than 2.87 g/dm^3 (80 g/ft^3) and ideally less than 2.15 g/dm^3 (60 g/ft^3), the total mass of noble metals of the catalyst or

catalysts being less than 2 g, preferably less than 1.6 g, ideally less than 1.2 g and optimally less than 0.8 g per liter of engine displacement (VH) or less than 3.5 g, preferably less than 2.8 g, ideally less than 2.3 g and optimally less than 1.8 g per 100 kW of rated horsepower (PNENN) of the gasoline engine.

Despite the small volume of the catalyst or the low loading with noble metal, the emission limits for EU IV are fulfilled with the inventive internal combustion engine installation. This is the case especially also for aged catalysts. Such aging can be achieved, for example, by alternately acting upon the catalyst with exhaust gases from an at least 90% full-load operation and thrust cut-off. Pursuant to the invention, investigations were conducted with similar internal combustion engine installations, which differ with regard to the fuel injection. On the one hand, measurements were carried out with an intake manifold injector, on the other, with directly injected gasoline engines. They showed that the directly injected gasoline engines, aside from having an up to 7% higher rated horsepower, produced fewer HC emissions. Fewer HC emissions were achieved when the following specifications were present:

- The injection nozzle is installed in the region from -20° to +50° relative to the circular cross section of the cylinder (negative degrees correspond to the alignment with respect to the cylinder head, 0° corresponds to the alignment parallel to the circular cross-section of the cylinder, positive degrees correspond to the alignment in the direction of the crankshaft).

- The center position of the injection jet at the outlet of the injector of the injection nozzle has an injection angle ranging from -5° to -45° or 70° to 90°, relative to the circular cross-section of the cylinder (alignment here above).

- The injection pressure is at least 40 bar and preferably at least 60 bar. Preferably, the maximum injection pressure is 2000 bar and especially 1000 bar

- The injection commences at 330° to 150° before top dead center and especially at 280° to 250° before top dead center.

With these specifications, individually or also in combination, an injection is achieved in such a manner, that the fuel is distributed adequately in the combustion space and develops only slight wall film effects. In the case of similar catalysts, even after they have aged, up to 50% less emissions, especially of hydrocarbons, is achieved by these means in comparison with the intake manifold injector. With that, it becomes possible to provide directly injected gasoline engines, especially if they fulfill at least one of the above specifications, with the inventive catalyst volume or the inventive specifications for loading the catalyst with the noble metal, the EU IV standard nevertheless being fulfilled in the NEFZ even after specified aging.

Pursuant to the invention, a catalyst volume (KV) of less than 0.7 and especially of less than 0.6 x the engine displacement (VH) is preferred. For determining the catalyst volume (KV) over the rated horsepower of the engine (PNENN), a catalyst volume (KV) of less than 1.15 L and especially of less than 1.00 L per 100 kW of rated horsepower of the engine (PNENN), is preferred, a catalyst volume (KV) of less than 0.85 l per 100 kW of rated horsepower of the engine (PNENN) being optimum.

The average specific loading of the catalyst or catalysts with noble metal preferably is $\leq$ 2.87 g/dm^3 (80 g/ft^3). If at least one pre-catalyst is present, the specific loading of the pre-catalyst or pre-catalysts can be up to 70%, preferably up to 50% and optimally up to 30% higher than the specific loading of the main catalyst or

catalysts with noble metal. Preferably, the total mass of noble metal of the exhaust gas purification system is less then 1.7 g, especially less than 1.4 g, optimally less than 1.2 g and, in a perfect system, less than 1.0 g per liter of engine displacement VH or preferably less than 3 g, especially less than 2.5 g, optimally less than 2.2 g and, in a perfect system, less than 2 g per 100 kW of rated horsepower of the gasoline engine.

The directly injected gasoline engine is capable of stratified operation in less than 7%, especially in less than 5%, preferably in less than 3% and optimally in 0% of operating points. The gasoline engine preferably is a naturally aspirated engine.

Numerous variations are possible for designing the catalyst system. For example, a single catalyst, at least two catalysts arranged in parallel, a main catalyst with at least two pre-catalysts, arranged in parallel, and pre-catalysts, arranged in parallel, with main catalysts, arranged in parallel, can be used.

When a single catalyst is disposed downstream from the gasoline engine, it is preferably removed less than 800 mm, especially less than 500 mm, optimally less than 300 mm exhaust gas pipeline length from the nearest outlet valve. The catalyst system may, however, also have at least two catalysts, which are connected in parallel and are disposed in each case less than 800 mm, preferably less than 500 mm and optimally less than 300 mm exhaust gas pipeline length behind the nearest outlet valve.

In the case of a different embodiment of the inventive internal combustion engine installation, the catalyst system has a pre-catalyst, which is followed by a main catalyst, which, preferably, is at a distance of more than 100 mm from the pre-catalyst. Similarly to the embodiment with a single catalyst, the pre-catalyst preferably is disposed less than 800 mm and preferably less than 500 mm exhaust gas pipe length behind the nearest outlet valve. Moreover, the pre-catalyst

has a volume of not more than 70%, preferably of not more than 50% and ideally not more than 30% of that of the main catalyst, which follows it.

Pursuant to the invention, an arrangement with at least two pre-catalysts, which are connected parallel to one another and disposed in each case less than 800 mm, preferably less than 500 mm and ideally 350 mm exhaust gas pipeline length behind the nearest outlet valve, and at least one main catalyst, which follows these pre-catalysts, is also possible. Moreover, the pre-catalysts together have a volume of not more than 70% and preferably not more than 50% of the downstream main catalyst or catalysts.

When a single catalyst is used or when there are pre-catalysts and main catalysts, the single catalyst and the main catalyst or catalysts are based preferably on a ceramic support. This ceramic support preferably has a cell density of more than 500cpsi and the product of the cell density (in cspi = sales per square inch) and the cell wall thickness (in mil = thousandths of an inch) is less than 2700, corresponding to 0.1063 when calculated on the basis of a cell density per square millimeter and a cell wall thickness in millimeters.

Alternatively, the pre-catalyst or pre-catalysts may have a support based on metal foil and a cell density preferably of more than 500 cspi, the product of the cell density (in cspi = cells per square inch) and the cell wall thickness (in μ = thousandths of a millimeter) being less than 30,000 and preferably less than 20, 000, corresponding to less than 46.5 and preferably less than 31 when the cell density is expressed in cells per square millimeter.

The inventive internal combustion engine installation with an exhaust gas purification system, which is not damaged by heat, ensures emission safety and according to the "Neue Europäischen Fahrzyklus" New European Driving Cycle – NEFZ) in spite of the significantly reduced noble metal costs.

Further preferred developments of the invention arise out of the remaining distinguishing features given in the dependent claims.

The invention is described in greater detail in the following in examples by means of the associated drawings, of which

FIG. 1 shows a diagrammatic representation of the internal combustion engine installation with a catalyst,

FIG. 2 shows a diagrammatic representation of the internal combustion engine installation with a pre-catalyst and a main catalyst,

FIG. 3 shows a diagrammatic representation of the internal combustion engine installation with two pre-catalysts and one main catalyst and

FIG. 4 shows a diagrammatic representation of the internal combustion engine installation with two pre-catalysts and in each case one downstream main catalyst.

FIGs. 1 to 4 each represent an inventive internal combustion engine installation 10, which has a gasoline engine 12 with a downstream exhaust gas installation 14, there being at least one catalyst for forming a catalyst system 16 in the exhaust gas installation 14.

FIG. 1 shows an internal combustion engine installation 10, which has a single catalyst 18, which is in the vicinity of the engine and optimally is disposed less than 300 mm exhaust gas pipeline length from the nearest outlet valve of the gasoline engine 12, the details of which are not shown. A pre-combustion engine installation 10, which has a pre-catalyst 20 and, downstream from the latter, a main

catalyst 22, which are at least 100 mm apart, is shown in FIG. 2. The length of the exhaust gas pipeline from the nearest outlet valve of the gasoline engine 12 to the pre-catalyst 20 is selected in a manner similar to that of the embodiment of FIG. 1. For the embodiment of the internal combustion engine installation 10 of FIG. 3, two pre-catalysts 20 are provided, which are assigned to different cylinders of the gasoline engine 12. A common main catalyst 22 is disposed downstream from the two pre-catalysts 20. On the other hand, FIG. 4 shows an embodiment of the internal combustion engine installation 10, which, as in FIG. 3, has to pre-catalyst 20, downstream from each of which, however, a main catalyst 22 is disposed, the two assemblies 24, 26 of the exhaust gas installation 14 being brought together behind the main catalyst 22. The exhaust gas pipeline lengths and the distances of the pre-catalysts 20 from the main catalysts are selected as described for the other embodiments.

List of Reference Symbols

10	internal combustion engine installation
12	gasoline engine
14	exhaust gas installation
16	catalyst system
18	catalyst
20	pre-catalyst
22	main catalyst
24	assembly of the exhaust gas installation
26	assembly of the exhaust gas installation